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A LABORATORY METHOD OF TEACHING ELEMENTARY CRYSTALLOGRAPHY

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IN spite of its apparent complexity, elementary crystallography is fundamentally simple, and may be successfully presented to college sophomores if taken up gradually and in a logical way. In connection with a course in elementary mineralogy given by the writer at Northwestern University from 1914 to 1917 the plan outlined in the following pages was found to be practical and satisfactory. It is published in the hope that it may be found useful to others called upon to teach the subject.

Twelve lecture periods of fifty minutes each, and twelve two hour laboratory periods, were devoted to crystallography in the writer's course. The laboratory was provided with a set of wooden crystal models and a collection of well developed natural crystals; and a quantity of report blanks, headed as shown below, but with type about twice as large as that here used, the whole sheet being about 9 by 11 inches.¹

CRYSTALLOGRAPHY REPORT

Tray.....

Name.....

No.	SYMMETRY						SYSTEM	CLASS	FORMS	
	PLANES			AXES					Sym- bol	NAME
	Axial		Diag- onal	Faces	Edges	Ver- tices				
	Ver- tical	Hori- zontal								

¹ This blank was modeled after that used by Dr. Edgar T. Wherry at Lehigh University.

Each student is required to have a note book, ruler, pencil, piece of cross-section paper, piece of cardboard, and a suitable elementary text-book. To each is furnished, also, a blue-print of the table of symmetry (see frontispiece), and mimeographed copies of the two sets of directions, given herewith. Students who conscientiously followed these directions were able at the close of the course to work out almost any crystallographic form and axial ratio of reasonably simple relationships.

DIRECTIONS FOR WORKING OUT AN UNKNOWN MODEL OR CRYSTAL

(Practice with known models and then with unknown models until these directions are thoroly understood.)

I. Work out the complete symmetry of the unknown, listing your findings on a report blank. Make your examination as follows (referring to textbook for definitions):

(a) Look for a center of symmetry. If present, every face, edge, and vertex has an *opposite, similar* one.

(b) Examine *each* face, edge, and vertex in turn to see if an axis of symmetry passes thru it. Your eye quickly detects an axis of symmetry if you look directly at the point of its emergence. To determine the character of an axis of symmetry, look squarely at it and either (1) note whether faces, edges, and points are disposed about it in pairs, threes, fours, or sixes, or (2) rotate the model upon this axis and observe how many times the appearance repeats during one revolution.

(c) With a piece of cardboard, note how many planes can be found that will divide the model into two halves, each of which is the *mirror-image* of the other. List these planes according to whether they are vertical, horizontal, or diagonal when the model stands oriented.

Note 1.—You can train yourself to show great facility in determining symmetry. In many cases, the eye catches the symmetry instantaneously.

Note 2.—Be careful not to count some of the elements of symmetry twice.

II. Refer to *Table of Symmetry*. Consider the total symmetry as listed for the unknown and locate its place in the table. This gives the crystal system and class of the unknown.

III. Orient the unknown. This may best be done by observing

- (a) The position in the unknown of axes that correspond in symmetry to the symmetry of the crystallographic axes (the symmetries of the crystallographic axes are shown in the *Table of Symmetry*).
- (b) The position of vertical planes of symmetry when such are also axial planes; *i. e.*, pass thru two axes.
- (c) The position of a horizontal plane of symmetry, if present. Such a plane passes thru the horizontal crystallographic axes.
- (d) The elongation of the unknown gives a clue to its orientation; for crystals are usually elongated along the *c*-axis.

Note 1.—Some crystals (isometric) are not elongated (are equi-dimensional).

Note 2.—Some crystals are elongated at right angles to the *c*-axis.

IV. Determine the forms present on the unknown, giving the name and symbol for each, as follows:

- (a) Hold the model oriented.

Example: If isometric, the *c*-axis must be vertical, the *a*-axis pointing toward observer, and the *b*-axis at right angles to observer.

- (b) Take up the largest and most prominent form first. Examine its face that lies nearest to your right (such a face will yield indices without minus signs). Note the slope of this face toward the imaginary crystallographic axes (extended if necessary). The intercepts of the face on the axes give the cutting-ratio or parameters of the face. Convert these parameters into indices. If necessary look in the book to see what form corresponds to the indices found.

Note 1.—If the form is complicated it may be necessary to lay a thin piece of cardboard on the face and note its inclination.

Note 2.—It is often advantageous to hold the model, *oriented and centered*, over cross-section paper upon which a plan of the crystallographic axes has been drawn. Then the cutting-ratio of the face may be determined graphically *on two axes at the same time* either by means of a piece of cardboard (see Note 1) or by laying a pencil on the paper so as to parallel the slope of the face and then rolling the pencil until it cuts one of the two axes at unity.

Note 3.—A simple form may often be determined by merely noting the number, shape, or disposition of its faces.

Note 4.—Remember that unless the unknown belongs to the isometric system, its axes are not all similar in length. Make allowance for this in estimating the parameters of a given face.

Note 5.—Of several forms the simplest is always assumed to be the *unit* form (the form whose cutting lengths, as shown in the indices, are unity, 1; for example, (111) is a unit pyramid; (221) is not.

Note 6.—Very complicated forms can only be approximately determined by these methods.

- (c) Take up the form next in prominence and proceed as under (b).

Note 1.—Each form is to be treated as if it occurred alone; the presence of other forms does not affect its relations to the crystallographic axes.

Note 2.—When three or more faces intersect in parallel lines these faces are said to occur in a *zone*. Look for zonal arrangement of faces; all faces in the same zone have a simple relation one to the other.

Example: Tetragonal prism 2d order—(100).
 " pyramid " —(101).
 " base —(001).

- (d) Take up the form third in prominence, and so on until all the forms are determined.

- V. Observe that the Trigonal System of the *Table of Symmetry* is the Rhombohedral class of the Hexagonal System as given in some textbooks.

(To be concluded)

IRIDESCENT QUARTZ FROM NEW YORK CITY

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IN connection with sewer excavations in the upper part of Manhattan Island considerable rock is being removed and allowed to remain in heaps for periods of a year or more. While examining a pile of such material at Pelham Parkway and 185th Street, Mr. W. A. Clay, of this city, recently found some quartz of rather unusual character. The material consists of slabs of gray massive quartz such as is common in the feldspathic mica schists of this part of Manhattan, with the partings covered with minute secondary quartz crystals in patches, within any one of which all the individuals lie in parallel position. Many of these patches of crystals, which may attain a diameter of an inch or so, show on the exposed faces of the tiny crystals a remarkably brilliant coloration, somewhat suggestive of labradorite, but with an even greater variety of hues than usually exhibited by the latter. On more freshly exposed surfaces blue and green colors predominate, but perhaps the most striking of all is the bright pink shown by the more weathered portions of the rock. Even to the naked eye the specimens are showy and attractive, but as microscopic mounts, examined with a low power objective, they are especially beautiful.

The exact nature and cause of these color phenomena are at first sight somewhat difficult to explain. Specimens were submitted to Mr. Frank J. Keeley, the well-known microscopist of Philadelphia, and he states as his opinion, after careful microscopic examination, that the appearance is due to a combination of "schiller" effect due to facetting resulting from etching, and possibly in part from secondary crystallization, together with colors produced by thin films of some sort on the surface of the quartz. These films probably consist of limonite or hematite, and owe their colors to their extreme thinness. It may be noted that on moistening a surface the colors disappear, but on drying again their brilliance is restored. Strong hydrochloric acid seems to attack the films somewhat, but only removes them with extreme slowness.

SUPPLEMENTARY NOTE ON METEORITIC IRON
PHOSPHIDE

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SINCE the publication of the previous note on iron phosphide in the Ruff's Mountain meteorite,¹ Dr. Merrill has worked up more of this material, and obtained an additional crystal possessing fairly well developed faces, which was submitted to the writer for examination. It proved to show the forms previously observed, 100, 110, and 111, and in addition the base, 001, and a form 362, represented by two well-marked tho irregular faces. The following additions to the angle-table (page 80) should accordingly be made:

Preceding No. 1; in the successive columns:

0, c, 001, 1, 1, blank, 0°00', blank, 0°00'.

Following No. 3, similarly:

4, x, 362, 1, 2, 26°00' \pm 60', 49°00' \pm 60', 26°34', 49°15'.

In addition to the corrections previously noted, on page 81 after the word class may be added: The class may well be scale-nohedral or bisphenoidal.

SIDERITE NODULES—INFORMATION WANTED

GEORGE P. MERRILL

U. S. National Museum

AMONG the accumulations of our older museums are not infrequently to be found peculiar forms, suggestive, so far as shape is concerned, of nothing more than the excretions of small animals like the domestic fowls. They are somewhat rugose and cracked on the outer surface, twisted and convoluted, usually not more than an inch or two in length, tapering to one or both ends and of a gray color, tho often oxidized to red or brown on the outside. Such are labelled sometimes simply "coprolites" or, in the case of one in the Shepard collection, "*Siderite album groecum from the tortoise.*" Within the past few years there has been received at the National Museum from Lewis County, Washington, specimens of precisely similar nature but much larger, sundry individuals weighing a pound or more and having such suggestive

¹ *Am. Min.*, 2, (6), 80-81, June, 1917; corrections, 2, (12), ii, Dec., 1917.

form that it has not been found advisable to display them in the exhibition cases. Recalling the identification of the smaller forms in the old collection, these were tested and found to consist almost entirely of carbonate of iron (siderite) without a trace of phosphoric acid. Under the microscope in thin section they show no concretionary or other structure than densely cryptocrystalline.

The question is: how do these peculiar forms occur and what is their origin? Their composition is certainly not what would be expected of coprolites. Do any readers of this magazine have information on the subject?

ABSTRACTS OF MINERALOGIC LITERATURE

ORIGIN OF FLINTS. FREDK. CHAPMAN. National Museum, Melbourne. *Nature*, No. 2501, 85, 1917.

Black flints with the characteristic white coating, indistinguishable from the English flints, occur in nodular and tabular form, with chalky Miocene limestone, in South Australia and Victoria. The flints are often crowded with silicified remains of organisms, representing a more or less complete replacement of chalky ooze. Below these Tertiary flint layers is an impervious bed, a factor which induced the deposition of diffused silica. S. G. C

GENESIS OF ASBESTOS AND ASBESTIFORM MINERALS. Discussion by J. C. BRANNER, J. A. DRESSER, R. P. D. GRAHAM, and G. P. MERRILL. *Bull. Am. Inst. Mining Eng.*, 1917, 397-405.

Many objections to the conclusions of Taber (abstd. in *Am. Min.*, 2, 69, May, 1917) are raised. In particular it is pointed out that vein-cavities are more likely due to shrinkage than to expansion, that instead of fibrous minerals pushing the walls apart it is more likely that they are replacements of the wall rock, and that serpentine is a deep-seated rather than superficially-formed mineral. E. T. W.

SPECTROGRAPHIC STUDY OF PORTUGUESE URANIUM AND ZIRCONIUM MINERALS. A. PEREIRA-FORJAZ. *Compt. rend.*, 164, 102-103, 1917.

The minerals noted are autunite, torbernite, carnotite, walpurgite, troegerite, zeunerite, and zircon. On spectroscopic examination many elements were found in addition to those required by the formulas. E. T. W.

THE COLORS OF MOTHER-OF-PEARL. A. H. PFUND. *J. Franklin Inst.*, 183, 453-464, 1917.

The colors are found to be due diffraction of light by edges of laminae and interference of light by reflection from parallel laminae. The thickness of the laminae ranges from 0.4 to 0.6 microns. E. T. W.

DIAMONDS IN CALIFORNIA. W. H. STORMS. *Min. Sci. Press*, **114**, 273-275, 1917.

The possible sources of the diamonds found in gold-bearing gravels in California are discussed. Basic igneous rocks and micaceous sandstones like those in which diamonds occur in other regions are present in the neighborhood, but the California gems have never been definitely traced to such a source.

E. T. W.

REFRACTIVE INDICES OF THE RHOMBOHEDRAL CARBONATES. P. GAUBERT. *Compt. rend.*, **164**, 46-49, 1917.

Measurements are given for a number of carbonate minerals, with some analytical data, altho the results are not sufficiently accurate to add much to previous knowledge.

E. T. W.

PALAEOPHYSIOLOGY: THE ORGANIC ORIGIN OF SOME MINERALS OCCURRING IN SEDIMENTARY ROCKS. J. V. SAMOILOV. *Min. Mag.*, **18**, (84), 87-98, 1917.

Deposits of nodular barite occur at a number of Russian localities in sedimentary rocks, clays, etc. Attention is called to the occurrence of barium sulfate in certain Rhizopods, the *Zenophyophora*. Similar deposits of celestite are found, and are believed to be due to the accumulation of strontium from the skeletal parts (shells) of marine organisms. Copper is found in the blood of certain Crustacea and Mollusca, vanadium in the blood of Ascidia, and manganese in certain land and fresh water mollusca. These facts have an important bearing on the origin of sedimentary mineral deposits. Such deposits occur at definite geological horizons and probably imply an abundant and widespread development of the organisms during certain periods.

S. G. G.

THE NUMERICAL RELATION BETWEEN THE ZONES AND FACES OF A POLYHEDRON. E. S. FEDOROV. *Min. Mag.*, **18**, (84), 99-100, 1917.

See *Am. Min.*, **2**, (7), 96, 1917.

THE CRYSTALLIZATION OF PARAHOPEITE. A. LEDOUX, T. L. WALKER AND A. C. WHEATLEY. *Min. Mag.*, **18**, (84), 101-106, 1917.

See *Am. Min.*, **2**, (7), 96, 1917.

ON TAPIOLITE IN THE PILBARA GOLDFIELD, WESTERN AUSTRALIA. E. S. SIMPSON. *Min. Mag.*, **18**, (84), 107-121, 1917.

See *Am. Min.*, **2**, (5), 68, 1917.

THE USE OF ORTHOGRAPHIC PROJECTION IN CRYSTALLOGRAPHY. H. HILTON. *Min. Mag.*, **18**, (84), 122-129, 1917.

THE USE OF A SLIT IN DETERMINING REFRACTIVE INDICES WITH THE MICROSCOPE. J. W. EVANS. *Min. Mag.*, **18**, (84), 130-132, 1917.

- MAGNESIAN TOURMALINE FROM RENFREW, ONTARIO. E. L. BRUCE. *Min. Mag.*, **18**, (84), 133-135, 1917.
See *Am. Min.*, **1**, (3), 49, 1916.
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PRESSURE PHENOMENA ACCOMPANYING THE GROWTH OF CRYSTALS. STEPHEN TABER. Univ. S. Carolina. *Proc. Nat. Acad. Sci.* **3**, 297-302, 1917.

The crystallization of solutions of ammonium nitrate in porous vessels was studied and evidence found that considerable pressure was exerted by the growing crystals. The author extends the theories derived from such observations to explain the phenomena accompanying crystallization of various minerals in the earth. E. T. W.

ZONAL GROWTH IN HEMATITE AND ITS BEARING ON THE ORIGIN OF CERTAIN IRON ORES. R. B. SOSMAN AND J. C. HOSTETTER. Geophys. Lab. *Bull. Am. Inst. Min. Eng.*, **1917**, 933-942.

A good crystal of hematite from Elba was found to contain considerable FeO, arranged in zones, being highest toward the base. This indicates deposition from vapor or solution, and continuously changing conditions of temperature, pressure and concentration during crystal growth. E. T. W.

THE FERROUS IRON CONTENT AND MAGNETIC SUSCEPTIBILITY OF SOME ARTIFICIAL AND NATURAL OXIDES OF IRON. R. B. SOSMAN AND J. C. HOSTETTER. *Bull. Am. Inst. Min. Eng.*, **1917**, 907-931.

Hematites containing magnetite in solid solution show magnetic susceptibility proportional to the FeO content. There is also a rare highly ferromagnetic form of Fe₂O₃. Martite gives evidence of being usually a pseudomorph after magnetite, its constituent granules or fibers being such solid solutions, and the susceptibility suggests its formation at high temperatures. E. T. W.

THE CONSTITUTION OF PYRITE AND ALLIED MINERALS. W. H. GOODCHILD. *Mining Mag.*, **16**, 253-258, 1917.

By a study of specific gravity and volume relations, the author concludes that the formulas of such minerals as pyrite are much more complex than the usual formula, FeS₂, would indicate; that the sulfur in pyrite represents the maximum amount in the minimum space; and that the sulfur in pyrite is in the rhombic form, while that in marcasite corresponds to the monoclinic. While pyrite, marcasite, and arsenopyrite are formed with contraction in volume, in the case of chalcopyrite there is an increase, thought to be due the Fe and Cu atoms competing for the extra sulfur. E. T. W.

THE ULTRAVIOLET TRANSPARENCY OF CERTAIN COLORED MEDIA. H. W. L. ABSALOM. *Phil. Mag.*, **33**, 450-455, 1917.

Most colored substances are opaque toward the extreme violet end of the spectrum, but minerals such as zircon and topaz are transparent there, showing that their colors are due to colloidal metals. A similar relation holds for solutions of metals in liquid ammonia. E. T. W.

ARTIFICIAL COVELLITE. J. M. FRANKEL. *Eng. Mining J.*, **104**, 252, 1917.

In contact with rubber both chalcocite and metallic copper have been found to change into covellite. E. T. W.

DO FIRECLAYS CONTAIN HALLOYSITE OR CLAYITE? J. W. MELLOR. *Trans. Engl. Ceram. Soc.*, **16**, 73-84, 1917.

The term "clayite" is used for colloidal kaolinite. This shows a transformation at 500°, indicated by a change in the thermal curve, while halloysite shows no marked change at this point. Mixtures of colloidal Al_2O_3 and SiO_2 act like halloysite. The mineral makeup of various natural clays can accordingly be determined by heating them to this temperature and noting whether or not a break occurs. A number of English fireclays are found to consist chiefly of "clayite." E. T. W.

TRIBOLUMINESCENCE. A. IMHOF. *Physik. Z.*, **18**, 78-91, 1917; thru *Science Abstracts*, (A), **20**, 266-267, 1918.

The subject of light produced by friction was studied, chiefly from the physical and chemical points of view. A table of 88 substances showing this phenomenon is given, several minerals being included. The color of the light is most often blue, often yellow or orange, and rarely violet, white, or red; the last is in fact shown only by a few minerals. E. T. W.

DIAMONDS FROM THE MOLTENO BEDS. E. H. L. SCHWARZ. *Trans. Geol. Soc. S. Africa*, **19**, 33-35, 1916.

Minute fragments of diamond have been found in wash at Molteno, S. Africa, associated with the heavy minerals garnet, rutile, monazite, etc. E. T. W.

SCAPOLITE-BEARING BOMBS FROM THE LAKE LAACH DISTRICT; REFRACTIVE INDICES OF SULFATE-SCAPOLITE. R. BRAUNS. *Neues Jahrb. Min. Geol.*, **1917**, I, 9-44; thru *J. Chem. Soc.*, **112**, II, 325, 1917.

A number of analyses of scapolite and the rocks containing it are given, with the optical constants of silvialite or sulfate-scapolite. E. T. W.

AUGITE FROM STROMBOLI. S. KOZU AND H. S. WASHINGTON. *Am. J. Sci.*, [4], **45**, (6), 463-469, 1918.

Augite occurs abundantly as loose crystals in the fine ashes that cover the slope encircling the active crater terrace. The optical characters and an analysis are given. S. G. G.

IDENTIFICATION OF MOLYBDENITE. T. S. FUCHS. *Eng. Min. J.*, **105**, (22), 991, 1918.

The following accurate and rapid method is given for identifying molybdenite, and also getting it into solution: A piece of caustic potash is melted, and the mineral added. In five minutes, molybdenite swells, dissolves, giving the mass an intense reddish-yellow color. S. G. G.